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ABSTRACT

This research investigates how individual differences in strategic abilities affect problem solving and, more particularly, the extent to which hypothesis-generating skills predict effective hypothesis testing. Additional questions concerned the effects of content and timing of instructional advice on children's problem-solving strategies, and possible differential effects of such advice for children with varying hypothesis-generating skills. A total of 80 children 7 and 8 years of age worked four sets of alphabet transformation problems. Sufficient information resources were available to enable solution of all problems. In addition to general instructions and encouragement given to all subjects, three levels of instructional advice were provided, which varied according to the problem-solving stage at which advice was given and the specific relevance of the information. Results confirmed that, compared to other subjects, children initially able to generate viable hypotheses were more efficient in obtaining and applying information necessary to solve the problems. Problem-solving ability improved both when diagnostic advice followed an incorrect solution attempt and when directions for obtaining crucial information preceded a solution attempt. Children's subsequent problem-solving efficiency was improved by earlier advice. Advice was especially beneficial for children who showed initial strategic skills. These and other results are interpreted as supporting the trainability of intellectual skill components of inductive reasoning. (Author/RH)

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Strategic Abilities and Instructional Advice in Children's Problem Solving

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ABSTRACT

This research was designed to contribute to our knowledge of how individual differences in strategic abilities affect problem solving. Of special interest was the extent to which hypothesis-generating skills predict efficiency of hypothesis testing. Additional questions addressed in this study concerned the effects of content and timing of instructional advice on the problem-solving strategies of children, and the possible differential effects of such advice for children with varying hypothesis-generating skills. Eighty 7- and 8-year-old children worked four sets of alphabet transformation problems. Sufficient information resources were available to solve all problems. In addition to the general instructions and encouragement given to all children, there were three levels of instructional advice which varied according to the problem-solving stage at which advice was given, and the specific relevance of the information it contained. Results confirmed that children who initially were able to generate viable hypotheses were more efficient in obtaining and applying the information necessary to solve the problems. It was also found that problem-solving efficiency was improved both by diagnostic advice following an incorrect solution attempt, and by directions to obtain crucial information prior to a solution attempt. Further, children's subsequent problem-solving efficiency was improved by earlier advice. It was also found that advice was especially beneficial for children who showed initial strategic skills. These and other results are interpreted as supporting the trainability of intellectual skill components of inductive reasoning.

AIMS

The present study had several purposes. The first purpose was to empirically determine whether children who have the strategic abilities required to generate hypotheses and to develop plans to test their hypotheses are more efficient problem solvers than their age-mates who do not possess these strategies. These abilities were thought to establish the child's readiness for systematically and efficiently solving induction-type problems. The second purpose was to assess the potential benefits of giving instructional advice during the problem-solving process. Four levels of advice were operationalized to clarify the differential effects of tutorial assistance offered at different points in the solution process. Both content and timing variations of instructional advice were implemented, and immediate and delayed effects on problem solving were tested.

METHOD

Subjects

Eighty 7- and 8-year olds were randomly selected from a pool of 150 second- and third-grade children. There was approximately an equal number of males and females in each group. Since the protocols of the children showed no significant differences in strategic abilities or problem-solving efficiency due to age or sex, the data for all children were collapsed across these dimensions. Mean age of subjects was 8.2 years, with a range of mean ages for groups of 8.1 to 8.3 years. Mean IQ scores (based on the California Test of Mental Maturity) for the groups ranged from 105.7 to 111.2, with no significant differences among the groups.

Design

Children were assigned to one of 4 experimental groups which varied as to the timing and content of the instructional advice provided. These variations were operationalized by proposing three stages in solving the problems. Stage 1 was considered as the time during which the child must ascertain the requirements of the problem and the nature of its solution. During this time, the experimenter assessed the child's strategic abilities by asking him or her to state an hypothesis and describe a plan for checking it. Stage 2 was conceptualized as the time during which the child obtains criterial information. Stage 2 instructional advice did not consist of giving the information, but only in directing the child to search the appropriate reference material(s) in order to obtain it. Stage 3 was regarded as the solution-attempt stage during which the instructional advice consisted on confirmation or disconfirmation of the child's attempt. Children who received Stage 3 advice were recycled to Stage 2 following an incorrect attempt. Children in Groups A, B, and C were assessed in Stage 1, while children in Group D were not asked to state hypotheses and plans at Stage 1 and so served as a control for evaluating the possible instructional benefits of the readiness assessment. Children assigned to Groups A and B were given Stage 2 advice. Only children in Group A received Stage 3 advice.

Procedures

Children were tested individually in 30-minute sessions. Each child worked 14 transformation problems in order. The transformation used to create the stimulus materials consisted of scrambling the order of letters of the conventional alphabet and assigning them as

code equivalents for letters in the usual order (See Table 1). The children were carefully instructed in the concept of code as a special way of giving a message or instruction which must be "translated" in order to be understood. They were thoroughly familiarized with the nature and use of the reference materials available to help them work out problem solutions. These materials included a box of crayons clearly labeled in code; an alphabet book with common items grouped with the first code letter of their name (see Fig. 1), and a set of 31 flash cards with objects labeled in code on the reverse of the picture. Before presenting the first problem, children were required to demonstrate facility with the reference materials by correctly answering 3 practice questions.

Tasks

The 14 problems were grouped into 4 sets, and arranged according to difficulty (as determined by an earlier pilot study). Problems were presented in workbook format. The first set required the child to color a square according to the given code word. The second set required the child to select from 4 alternatives the correct code label of a given color square. Sets 3 and 4 required the child to decode object names (see Fig. 2 & 3); the former involved selecting from four alternatives the correct code label of a pictured object, while the latter involved selecting from 4 alternatives the picture named by a given code label.

Measures

Three measures were taken during each problem:

1. a measure of strategic abilities was made during stage one for each problem. This permitted the examination of possible transfer

effects of practice and/or instructional advice to improved overall readiness for systematically approaching subsequent problems.

2. a measure of inefficiency in using the reference materials for information with which to solve the problem. Inefficiency was measured during Stage 2 and was scored as the number of times the number of times the child searched irrelevant or redundant information. Information was considered irrelevant if possessing it did not contribute to solving the problem; information was scored as redundant if the child had already obtained it in an earlier search.

3. a tally of the number of unsuccessful solution attempts was used as an index of the child's problem-solving accuracy.

RESULTS

The results confirmed that children who initially were able to generate hypotheses and plans to test their hypotheses were at an advantage for efficiently obtaining necessary information and applying it to solve the problems. They made significantly fewer searches of irrelevant and redundant information than did children who did not possess these strategic skills. It was also found that instructional advice offered during Stage 2 (information search & retrieval) significantly improved problem-solving accuracy (See Figure 4). Children in Group A (who received Stage 2 advice) were found to search the reference materials with increasing efficiency on subsequent problems, thus gradually decreasing their reliance on the tutor (See Table 2). Diagnostic advice (given at Stage 3) following an incorrect solution attempt also showed immediate and delayed benefits. Children who received Stage 3 advice also showed an

improvement in efficiency and accuracy over problems both within and across sets

Also of importance was the finding that children with existing strategic abilities were more likely to show long-term benefits of Stage 2 and Stage 3 instructional advice than were children who did not yet show such processing. While instructional advice led to immediate benefits for the less strategic children, as long as they were assessed as "not ready", they continued to use the reference materials inefficiently. On the encouraging side, was the finding that "not ready" children who received the instructional advice became more "ready" over problems. This transition can only be due to the instructional advice, since children in Group C and Group D did not show an improvement in strategic ability over the experimental session.

CONCLUSIONS

These results support several conclusions. Addressing a developmental issue, the similarity of the protocols of the 7- and 8-year-olds supports the findings of earlier studies that the ability to use inductive processes to guide problem solving develops at about this age (Case, 1974; Tumblin & Gholson, 1981). With respect to the effects of strategic abilities, the results lead to the conclusion that the abilities involved in generating hypotheses and devising plans to test the hypotheses are reliable predictors of subsequent problem-solving efficiency and accuracy. The implication of this finding is that assessing these abilities provides information which is directly relevant and potentially helpful in designing instruction to promote and/or capitalize on individual children's existing skills.

The results concerning the benefits of instructional advice support the theory that there are specific strategic components required in solving a variety of problems (Sternberg, 1977, 1980, 1983). Because the children's responses to problems in this study were categorized according to 3 discrete stages, the present data permitted an analysis of this theory. The data showing differential utility of various kinds of instruction within the three stages strongly suggests that each individual stage is characterized by different information processes. The present findings also support the hypothesis that these processes can be taught (Sternberg, 1983). While some previous research establishes the general benefits of various forms of instruction and advice given to children and adult learners (Hayes-Roth, Klahr, & Mostow, 1981; Mims & Gholson, 1977; Sternberg & Ketron, 1982; Tumblin & Gholson, 1981), this study provides evidence concerning training children in specific components. Direct testing of components in Stage 1 clearly showed an effect due to instruction. As well, the improved Stage 2 and Stage 3 performance of children receiving pertinent instruction during these stages is also dramatic support for the "teachability" of problem-solving components.

TABLE 1

TRANSFORMATIONS USED IN THE STIMULUS MATERIALS

<u>STANDARD</u>	<u>CODE</u>	<u>STANDARD</u>	<u>CODE</u>
A	U	BAT	SUG
B	S	BEAR	SOUH
C	Z	BED	SOV
D	V	BOOK	SEEP
E	O	BOX	SEX
F	Q	BOY	SEL
G	T	BROWN	SHECK
H	R	BUS	SID
I	A	CAP	ZUJ
J	F	CAT	ZUG
K	P	COW	ZEC
L	M	CUP	ZIJ
M	N	DOG	VET
N	K	FAN	QUK
O	E	GOAT	TEUG
P	J	GREEN	THCOK
Q	Y	HAT	RUG
R	H	HEN	ROK
S	D	KEY	POL
T	G	LAMP	MUNJ
U	I	MAN	NUK
V	B	MOON	NEEK
W	C	NUT	KIG
X	X	PAN	JUK
Y	L	PEAR	JOUH
Z	W	PIG	JAT
		RAT	HUG
		RED	HOV
		SHIP	DRAJ
		SUN	DIK
		TOP	GEJ
		YELLOW	LOMMEC

TABLE 2

**READINESS AND ERROR DATA FROM GROUP A
WITH POINT-BISERIAL CORRELATIONS
CALCULATED FOR EACH PROBLEM**

PROBLEM	SUBJECTS PASSING STAGE 1 ASSESSMENT		SUBJECTS NOT PASSING STAGE 1 ASSESSMENT		
	N	MEAN ERRORS	N	MEAN ERRORS	CORRELATION*
1	19	0.00	8	2.13	0.80
2	22	0.00	5	2.20	0.98
3	26	0.00	1	3.00	0.96
4	27	0.07	0	--	--
5	25	0.04	2	1.50	0.88
6	27	0.00	0	--	--
7	27	0.00	0	--	--
8	27	0.00	0	--	--
9	19	0.00	8	2.00	0.81
10	25	0.12	2	2.50	0.88
11	25	0.04	2	2.00	0.86
12	19	0.15	8	2.20	0.80
13	25	0.16	2	2.50	0.80
14	24	0.20	3	2.33	0.77

* $p < .01$ for all correlations

FIGURE 1



FIGURE 2



SOV

JAT

RAG

SID

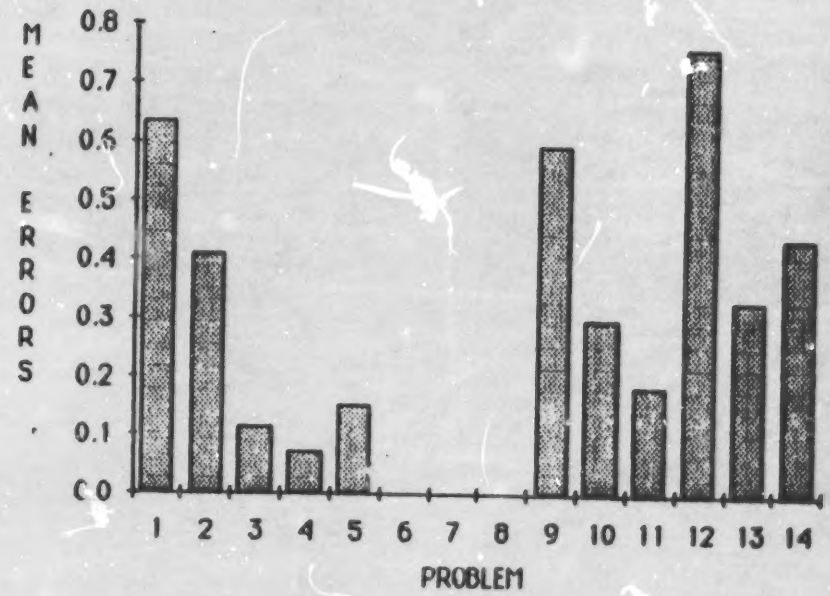
FIGURE 3



QUK

FIGURE 4

ERRORS BY PROBLEM FOR GROUP I



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